ANSWERS: Bond Energy calculations

1) Enthalpy change = ∑bonds broken – ∑bonds formed

Bonds broken	Bonds formed
C − H 413 × 6 = 2478	C=O 745 × 4 = 2980
C − O 358 × 2 = 716	O−H 463 × 8 = 3704
O − H 463 × 2 = 926	
O = O 498 × 3 = 1494	
+5614	− 6684

$\Delta_r H$ = −1070 kJ mol^{-1}

OR

Bonds broken = 4688 Bonds formed = 5758

2) Enthalpy change = bonds broken – bonds formed

$x = E_{(O–H)}$

(a) Bonds broken = 5(C–H) + 1(C–C) + 1(C–O) + 1(O–H) + 3(O=O)

(b) = 5(412) + 348 + 360 + x + 3(496)

(c) Bonds broken = 4256 + x *(4256)*

(a) Bonds formed = 4(C=O) + 6(O–H)

(b) = 4(743) + 6(x)

(c) = 2972 + 6(x) *(2972 + 5x)*

(d) –1379 = (4256 + x) – (2972 + 6(x))

(d) –1379 = 1284 – 5 (x)

(d –2663 = – 5(x)

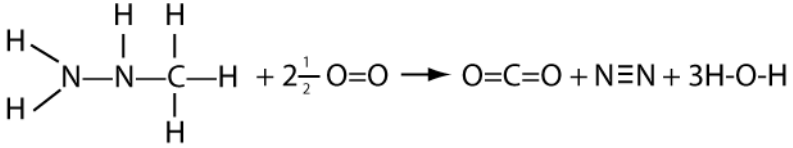
x (O–H) = 533 kJ mol^{-1} OR 532.6 kJ mol^{-1}

3) Sum of bond energies broken – sum of bond energies formed

= (339 + 391) – (431 + 286)
= 730 – 717
= 13 kJ mol^{-1}

OR
(breaking and forming all bonds)
= (1242 + 339 + 1173) – (1242 + 286 + 782 + 431)
= 2754 – 2741
= 13 kJ mol^{-1}

4) (i) The energy required to break a bond
(ii)



$\Delta_c H^O = \Sigma E_B(\text{reactants}) - \Sigma E_B(\text{products})$

$= 3E_B(N–H) + E_B(N–N) + E_B(N–C) + 3E_B(C–H) + 2.5\ E_B(O=O)$
$– 2E_B(C=O) – E_B(N\equiv N) – 6E_B(O–H)$

$= 3\times391 + 163 + 286 + 3\times414 + 2.5\times498$
$–2\times804 – 941 – 6\times463$

= – 1218 kJ mol^{-1} (or heat released = 1218 kJ / kJ mol^{-1})

Bonds broken		**Bonds formed**					
3N–H	391 × 3 = 1173	2C=O	804 × 2 = 1608	N–N	163 = 163	N ≡ N	941 = 941
C–N	286 = 286	6O–H	463 × 6 = 2778				
3C–H	414 × 3 = 1242						
$2\frac{1}{2}$ O=O	498 × $2\frac{1}{2}$ = 1245						
Adds to	= 4109	Adds to	= 5327				

5) $H_2(g) + ½\ O_2(g) \rightarrow H_2O(s)$

H–H + ½ O=O → 2 × H–O

$\Delta_r H = 436 + ½\ (498) – 2\ (463)$

$\Delta_r H = –241$ kJ mol$^{–1}$

6) $\Delta_r H = \Sigma E_{\text{bonds broken}} – \Sigma E_{\text{bonds made}}$

$–41.2 = E_{CO} + (2 \times 463) – (2 \times 743) – 436$

$E_{CO} = –41.2 – 926 + 436 + 1486$

= 954.8 or 955 kJ mol$^{–1}$

Accept answer with 3 significant figures.

OR a valid process which uses bond energies to obtain correct answer

Eg $\Delta_r H = \Sigma E_{\text{bonds broken}}$ (positive values)

$+ \Sigma E_{\text{bonds formed}}$ (negative values)

7) $\Delta rH = \Sigma E\text{bonds broken} – \Sigma E\text{bonds made}$

$=(2 \times 436 + 498) – (4 \times 460) = +1370 – 1840$

= –470 kJ mol−1

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